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ELECTRICITY AS A MOTIVE POWER ON TRUNK LINES.

BY CORNELIUS VANDERBILT.

It would be interesting, though not instructive, to know how many people have prophesied, during the past ten years, that the day of the steam locomotive was at an end, and that the era of electricity as the motive power for railways was at hand, for one seldom takes a journey without hearing this view expressed by some fellow-passenger. When one considers the enormous growth of the trolley systems in this country, it seems to the layman—using this term in contra-distinction to that of engineer—quite natural to suppose that a slight extension will result in equipping the present steam roads with electric locomotives or motor cars run in trains. It is the object of this short paper to consider, in a very general way, the reasons for the extension or non-extension of the trolley system, and to draw certain conclusions from an examination of the principles which underlie the question. The conditions to be met in the different parts of the country, caused by the differences in the communities served by the various roads, as well as numerous minor matters, require a different analysis to be made of each line, but certain general principles are the same for all, and we will therefore attempt to examine these, excluding as far as possible any specific railway or group of roads.

From the stand-point of those in charge of the railways in this country, there is only one object in view when a change is made in methods of operation, whether the change be great or small, from the consolidation of a number of roads down to the minutest improvement in rolling-stock. That object is the production of an increased net revenue; and it may be brought about either by a reduction in the cost of transporting freight and passengers, or by providing such additional facilities that the volume of traffic will be increased, or that higher rates may be charged.

It may be accomplished in the last-mentioned manner if the change insures a measure of comfort and convenience to shippers and passengers which more than counterbalances the question of cost or price of the service rendered. It is evident, therefore, that, under certain conditions, an increased cost of transportation may be, in the end, economical and advantageous to the railway if it is accompanied by a great increase in facilities or convenience to those using the road. Some thought on this latter point discloses the fact that this will be the case almost exclusively in passenger traffic, and may be omitted in considering the transportation of freight. There might be some hesitancy in making this last assertion, had not the experience of many American roads during the past decade shown that a decrease in the cost per ton-mile was accompanied by a greater benefit to the road than was obtained by any increase in convenience to shippers of freight. The results obtained by the methods in use on the roads in the Northwest clearly show the truth of this statement.

It is apparent from the above that, before any change from the present system of motive power is made, the result must promise either a more economical method of transportation, or such an increase in the volume of traffic as will insure an increased net revenue. In any case, the first point to be considered is the actual cost to a road of transporting a given weight a given distance. The unit generally used in considering this question in freight traffic, is the cost per ton-mile, or the cost of hauling one ton one mile; but there is no corresponding unit for passenger traffic, unless we should take the cost of transporting one passenger one mile, assume an average weight per passenger, and multiply it by the number of passengers weighing one ton. It is, however, not necessary to do this, for, taking the subject as a whole, a simple method for purposes of comparison is to take, first, the cost of a unit amount of fuel; second, the amount of useful work realized from this fuel at the driving wheels; third, the cost of operation or handling trains; fourth, the cost of repairs to the machinery; and, fifth, the cost of repairs to the road-bed.

In comparing the present motive-power system with the proposed system of electric traction, we should, therefore, make separate comparisons of each of these points and thus arrive at our conclusion. We must, then, compare the cost of equipping a road with either system, and determine which will bring in the greatest return on the capital invested. The cost of the fuel naturally varies greatly in different parts of the country; but, with one exception, we may take it as being equal on any given road for both systems, omitting certain cases where coal of different quality may be used in power-houses and on locomotives, since, with coal or oil, the only other difference in cost would be found in the cost of its transportation from the point of delivery to the point of consumption. This would, in all probability, be equal in both plans, if we assume the distance between power-houses to be approximately the same as the distance between coaling stations of locomotives. The only exception to this is the case in which water power could provide the initial "fuel"; but, as falls capable of generating sufficient power are not generally found in the proper or convenient positions, and as their "head" or pressure varies greatly with the seasons, we might omit this case from the discussion, though it should not be entirely passed over without considering its possibilities. It is impossible to compare the cost of such power as a fuel to the cost of the actual coal or oil, but its cost after conversion to electricity could be compared to the cost of electricity produced by means of coal or oil, boilers, engines and dynamos. And it thus leads us to the second point to be considered—that is, the amount of useful work realized at the driving or motor wheels from the initial fuel.

To compare the systems under consideration from this point of view, we should determine what proportion the amount of work realized bears to the initial amount of work put into the "machine," or what is termed in engineering the efficiency. This brings us to the vital point of the discussion. The steam locomotive system is a direct-acting "machine"—that is to say, it obtains the power at the drivers by means of a single conversion of energy; while the electric system must necessarily use a double or multiple conversion of energy before the power is obtained at the motor wheels. It is an axiom in physics that in any conversion of energy a loss must take place, and, therefore, if the first conversion—that from coal or oil to steam—is equal in both cases, there will be a lower total efficiency in the case of the double than in that of the single conversion.

But it so happens that, in the first conversion, the efficiencies of the systems under comparison are not equal, for the locomotive efficiency is, as a rule, lower than the efficiency obtained from boilers and engines in a power-house. The higher efficiency of the latter is due to the fact that it is possible to use larger units; that they are stationary; that the engines are condensing; that it is not necessary to force the boilers to the same extent as the boilers of locomotives; and that there is a smaller loss in the mechanism of the engine itself. The efficiency of the former system is its total efficiency, since the steam is applied to useful work at the drivers without any further changes, while, for the electric system, we must convert the power obtained from the steam into electricity, transport it along the rail and use it in the motors on the train. We must, therefore, consider the losses due to this process in order to determine its total efficiency.

These losses, depend, primarily, on the distance between power-houses if continuous current be used, and on the location of sub-stations as well as power-houses if alternating current be employed. The greater portion of this second loss is due, in long-distance transmission, not to the actual loss in the electrical machines,—for the present efficiency of dynamo, motor, convertor and alternator leaves so small a margin for improvement that, even should they be still further perfected, the result would have little effect on the total,—but to the transmission or line loss. Therefore, up to a certain point, we may say that the further apart the power-houses and sub-stations are placed, the smaller will be this efficiency. It is possible under certain conditions so to space the fixed electrical plant that a total efficiency from the fuel to the power at the wheels will be obtained equal to that obtained in a steam locomotive, and it is also possible, by a still closer spacing, to obtain an efficiency slightly in excess of this.

The location of the fixed electrical plant thus determines the total efficiency of the system, and materially affects both first cost and cost of operation. It also affects the possibility of using water power; for, unless the falls are situated at frequent intervals along the line of a railway—an impossibility except in mountainous districts—the line loss precludes its general adoption.

We now come to the third point for comparison—that of the relative cost of operation, and while it is impossible to determine this and the remaining two points with accuracy, yet we may discover approximately what the results in substituting electricity for steam would be. Taking the items properly chargeable to operation or conducting transportation, we find that there should be no difference, under either plan, in the expense of superintendence, station service, telegraph or signal operation, men employed as switchmen and flagmen or men at present employed in the roundhouses. It is also fair to assume that the cost of general supplies, such as oil, waste, etc., would be equal in both cases. The remaining item is the train service, which may be divided into wages of engine and train crews, and general train supplies. The latter should be equal for both systems, so we need only consider the former. It is impossible to run a freight train with safety with a smaller number of men than the number in an ordinary crew; while in the engine crew, should the third rail be used, it would be possible to dispense with the services of a fireman, though it would be so unsafe to have only one man in the cab that an assistant motorman should be employed. This is not done on some of the electric passenger lines now in operation, such as the elevated roads in New York, but on a trunk line the chances of accident to an engineman are far greater, owing to the volume of traffic and to the speeds run, than on any suburban road, and it is, therefore, possible that, should a road equipped with the third rail attempt to operate with only one man in the cab, either the resulting accidents or the Inter-State Commerce Commission would force the employment of a second. The above statements apply with equal force both to passenger and freight trains, and, as the wages of train and engine crews should not differ whether electricity or steam be used, we come to the conclusion that the relative cost of conducting transportation, exclusive of the force at work in the power-houses and sub-stations along the line, should be equal in both cases.

The cost of maintenance of a locomotive on a railway of the first class should be about five cents per mile run. This cost naturally varies in different parts of the country, depending on the life, amount of service, quality of coal and water used, type of boiler and engine, and the general attention or care given; but five cents is a fair maximum figure.

There is, unfortunately, no figure for cost of repairs to electric motors and equipment with which this can be directly compared, but, judging from results obtained on such lines as the elevated roads of Chicago and New York, this figure is, if anything, slightly higher for the latter, comparing the maintenance charges of the total number of motors on a train, and the proportionate power-house repairs, with the maintenance of a single steam locomotive. The cost of maintenance of the cars employed should not differ in either plan, unless motor cars be used, and this could at present only be done in passenger service, for an attempt to equip freight cars with motors, and so take advantage of the weight of load for adhesion, would be entirely impracticable, unless the road adopting this arrangement refused to allow the cars so equipped to leave its own line. It is difficult to compare the relative cost of repairs to road-bed; but, despite the much talked of ill effects of the "hammer blow," it seems probable that electric traction would increase this charge, by reason of the additional cost of maintaining the third rail, and the complication at switching points and in yards.

It is now proper for us to consider the comparative first costs. There will be a greater first cost for any electric traction system, due principally to the cost of power houses, sub-stations and third rail, for the cost of rolling-stock equipment would be approximately the same as in steam-locomotive traction. If we anticipate an equal net return to the road in both cases, we should so place the power-houses and sub-stations for electric traction that we would decrease the fuel cost to the point where this saving will pay the interest (and power-house operating charges), on the amount of capital required for this system over that required for steam power. The possibility of doing this depends primarily on the density of the traffic on the road. In most cases, it is an impossibility, and the further we extend the principle, and so place our plant as to decrease the fuel cost, the more difficult is it to find a railroad with the required traffic density.

As has been previously stated, it is not the object of this paper to take up the consideration of individual roads; but it may be said that there are at present no roads in the United States deriving two-thirds of their total revenue from the transportation of freight—which is a fair proportion for a trunk line—on which this condition is found.

If we consider passenger traffic irrespective of transportation of freight, or if we view it from the stand-point of increasing traffic by increasing convenience, it assumes a different aspect.

We know from experience that, in this class of service, increased convenience and facilities in many cases more than compensate for increased cost of transportation. This convenience, as we may term it for want of a better word, includes general convenience to passengers, speed, number and frequency of trains, and is the all-important point in passenger traffic. Combining this with the fact that, after a certain density of traffic is realized, the fuel cost may be reduced, we have the reason for the success of the trolley system and for the adoption of electricity as motive power on certain metropolitan and suburban roads. In passenger traffic, the position of the road should determine, in the main, whether electricity is to be adopted, due consideration being given to the possibility of increasing the density of traffic by increasing the convenience, and a final judgment being rendered in its favor when it is seen that the density induced by this convenience will warrant the greater first cost and produce a larger net return (after deducting interest and cost of operation of the additional machinery) than will be produced if steam power is used. This net return may be procured either by a decreased fuel cost, if the density of traffic is sufficient, or by increased rates should the convenience be so increased that the passengers are willing to pay for it.

Many of the minor matters which would require discussion before the third-rail system was adopted on any road have been omitted in this paper—such as the protection of the live rails in yards, at switching points, and at grade crossings. Nor have questions of speeds, weights of trains, fluctuations in load requiring power-house apparatus out of all proportion to average power consumption, been considered. They are points too technical for discussion here.

That it is possible to use electricity as the motive power on trunk lines is not questioned. It is entirely possible from the engineering point of view; but, from the financial point of view, it is an impossibility except under the conditions mentioned above. How long it will remain so it is naturally out of the province of this paper to predict; but the possibility of certain improvements which would decrease the fuel cost in electric traction can be imagined, such as the successful working of oil engines in large units, or inventions that would reduce the line loss, etc.; while, on the other hand, improvements that would produce equal efficiency may be imagined for steam locomotives.

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